Peel strength of denture liner to PMMA and polyamide: laser versus air-abrasion

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Abstract: PURPOSE: This study investigated the effect of laser parameters and air-abrasion on the peel strength of silicon-based soft denture liner to different denture resins. MATERIALS AND METHODS: Specimens (N=180) were prepared out of three different denture base resins (Rodex, cross-linked denture base acrylic resin; Paladent, heat-cured acrylic resin; Deflex, Polyamide resin) (75 mm × 25 mm × 3 mm). A silicon-based soft denture liner (Molloplast B) was applied to the denture resins after the following conditioning methods: a) Air-abrasion (50 µm), b) Er,Cr:YSGG laser (Waterlase MD Turbo, Biolase Technology) at 2 W-20 Hz, c) Er,Cr:YSGG laser at 2 W-30 Hz, d) Er,Cr:YSGG laser at 3 W-20 Hz, e) Er,Cr:YSGG laser at 3 W-30 Hz. Non-conditioned group acted as the control group. Peel test was performed in a universal testing machine. Failure modes were evaluated visually. Data were analyzed using two-way ANOVA and Tukey's test (α=.05). RESULTS: Denture liner tested showed increased peel strength after laser treatment with different parameters (3.9±0.4 - 5.58±0.6 MPa) compared to the control (3.64±0.5 - 4.58±0.5 MPa) and air-abraded groups (3.1±0.6 - 4.46±0.3 MPa), but the results were not statistically significant except for Paladent, with the pretreatment of Er,Cr:YSGG laser at 3 W-20 Hz. Polyamide resin after air-abrasion showed significantly lower peel strength than those of other groups (3.1±0.6 MPa). CONCLUSION: Heat-cured acrylic resin, PMMA, may benefit from Er,Cr:YSGG laser treatment at 3 W-20 Hz irradiation. Air-abrasion of polyamide resins should be avoided not to impair their peel bond strengths to silicon-based soft denture liners.

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Original article

Peel strength of denture liner to PMMA and polyamide: laser versus air abrasion

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Abstract

This study investigated the effect of laser parameters and air abrasion on the peel strength of silicon-based soft denture liner to different denture resins.

After preparation of the specimens (N=180), a silicon-based soft denture liner was applied to the denture resins after the following conditioning methods: a) air abrasion (250 μm), b) Er;Cr;YSGG laser at 2 W-20 Hz, c) Er;Cr;YSGG laser at 2 W-30 Hz, d) Er;Cr;YSGG laser at 3 W-20 Hz and e) Er;Cr;YSGG laser at 3 W-30 Hz. The non-conditioned group acted as the control group. The peel test was performed in a Universal Testing Machine.

The silicon-based soft lining material tested showed similar peel strength with and without laser treatment. Heat-cured acrylic resin, PMMA, may benefit from Er;Cr;YSGG laser treatment at 3 W-20 Hz irradiation. Air abrasion of polyamide resins should be avoided so as not to impair their peel bond strengths to silicon-based soft denture liners.

Keywords: acrylic, soft liner, laser

INTRODUCTION

In dentistry, soft denture liners have been an advantage for dentists because of their viscoelastic properties [1-3]. These liners act as shock absorbers to reduce and distribute the stresses on denture-bearing tissues and improve the intaglio denture surface [2,4-11]. The use of soft lining materials may promote the success of complete dentures by allowing the dentures to withstand masticatory stress where the denture-bearing tissues are relatively untolerated [10, 12-14]. Soft denture liners have several problems associated with their use; among the most serious of these is the failure of adhesion between the soft denture and the denture base [2,9,11,12,15]. Bond failure also creates a potential surface for bacterial growth, plaque, and calculus formation; therefore, frequent clinical evaluations and periodic replacement of soft denture liners are required [16]. The construction of dentures with permanent soft lining requires more laboratory time and extra costs related to the equipment and materials used; thus, it is essential that there is an adequate bond between the denture base and the soft lining material [4,6,7,17,18]. Previous studies [17,19,20] have showed that Molloplast-B soft lining material (Detax, Karl Huber GmbH and Co., KG, Ettlingen, Germany) is one of the most preferred materials for long-term clinical use.

PMMA denture base resin and silicone-based lining materials have different molecular structures and cannot be chemically bonded [9, 21]. Bonding between the denture base resin and silicone-based lining material relies completely on an interfacial adhesive [9,21]. Adhesion to polymeric materials usually requires some surface pretreatments to help improve the wettability characteristics of these materials [4,22]. Several studies have investigated methods to improve bond strength between liners and acrylic base resins. While some studies have investigated the effect of roughening by airborne particle abrasion on the bond strength of soft liners to acrylic base resins [4,11,18,23-26], other studies were interested in the use of chemicals, including acrylic resin monomers [9,23,27] and their combinations [28-31], on the bond strength of soft liners with denture resins; however, controversial results were reported. Although some studies [4,25,32] have reported that an improvement of interface strength was gained by roughening the surface denture base before applying the lining material, others [1,11,26] have shown no effect or negative effects of the roughening process on the bonding of the two materials.

Since the development of the first working laser by Maiman in 1960, advances in laser technology have resulted in the quick adoption of laser technology for use by many in the field of dentistry [11, 24, 33]. Recently, lasers have been found to be effective in altering the surface of materials [4, 11, 24]. However, few studies [1,4,11,18,24] have used different types of lasers for the surface pretreatment of denture base resins before applying soft liner materials to improve the bond strength of these materials. To the best of our knowledge, no previously published studies consider the use of an Er;Cr;YSGG laser (Waterlase MD Turbo, Biolase Technology) to strengthen the bond between denture base resin and soft liner. When using the Er,Cr:YSGG laser at appropriate air and water settings, the temperature of the target tissue has been shown to have no change or to fall up to 2ºC below the normal temperature. The Er,Cr:YSGG laser has a high affinity for water. The uniqueness of this system lies in the presence of an air/water spray, which has a dual role: to assist in the cutting and to serve as a coolant to keep the surface temperature low and to eliminate any potential detrimental thermal side-effects. This gentle treatment on the tissue makes it very attractive as an alternative to conventional methods.

Several types of tests have been used to assess the bond strength of soft lining materials to denture base resin [4,6,8,11,34]. The three most commonly used are lap shear, tensile tests and peeling tests [34,35]. The usefulness of these methods has been discussed. Testing the soft liners using peel testing is believed to be the best simulation of the clinical setting for the failure of soft lining materials [8,11,34,35].

Currently, thermo-injectable, semi-rigid, high-impact polyamide resins are thought to be a valid alternative to the conventional acrylic resins due to their superior aesthetic and functional characteristics and physicochemical qualities [36,37]. Unfortunately, there is very limited knowledge about their clinical performance. The efficiency of the relining procedures for these materials has yet to be well studied.

The aim of the present study was to evaluate the effect of air abrasion and laser treatment with different pulse durations on the bond strength of a silicone-based soft denture liner (Molloplast-B) to three different commonly used denture resins [a polyamide based high impact thermo-injection molded denture material (Deflex; Nuxen SRL, Ayacucho 1053 3-A, Cap. Fed. Buenos Aires, Argentina), a heat-cured cross-linked acrylic resin (Rodex; Rodont, Srl Milan, Italy Rodex) and a conventional heat-cured acrylic resin (Paladent; Heraeus Kulzer GmbH, Wehrheim, Germany)] using the peel test. The null hypothesis was that the air abrasion and laser treatment with different pulse durations would improve the peel bond strengths of silicone-based soft denture liner to different denture resins.

MATERIALS AND METHODS

Three different denture base resins, a cross-linked denture base acrylic resin (Rodex; Rodont, Srl Milan, Italy), a heat-cured acrylic resin (Paladent; Heraeus Kulzer GmbH, Wehrheim, Germany) and a polyamide resin (Deflex; Nuxen SRL, Ayacucho 1053 3-A, Cap. Fed. Buenos Aires, Argentina), as well as a heat-polymerized silicone-based resilient liner (Molloplast-B; Detax, Karl Huber GmbH and Co., KG, Ettlingen, Germany) were used in this study. The brand names, types and manufacturers of the materials used in this study are presented in Table 1.

Sample preparation

For the preparation of peel test materials, a mold (65 x 10 x 3.3 mm) was prepared from sheet aluminum, and with the help of this mold, specimens were produced from three plates of pink wax. For every test material, 66 wax specimens were made (11 for each group), and a total of 198 wax specimens were produced. The heat-cured specimens were prepared in stone molds in denture flasks and were cured in a manner similar to that used in conventional denture construction.

After polymerization, the cured denture base resin plate was removed from the flask and trimmed, and the surface to be bonded was smoothed on 240 grit silicon carbide papers, cleaned and dried. The polyamide resin base was also prepared according to manufacturer's instructions. A total of 198 test specimens consisting of 66 Paladent, 66 Rodex and 66 Deflex specimens were prepared using these techniques. The specimens were placed in covered denture caps and stored in distilled water at 37°C until the surface treatment simulated typical denture storage. Before surface treatments, the specimens were allowed to air dry for 24 hours. Six samples of each material (n=18) were selected randomly to be investigated by scanning electron microscope (SEM; EVO L10, Carl Zeiss, Oberkochen, Germany) for differences in surface morphology after pretreatments. To create a space for the soft liner material, the acrylic specimens were reflasked using fresh pink wax material. After the removal of the wax, flasks with each acrylic specimen were randomly divided into six subgroups. There was not any pretreatment in the control group. Other test groups were either sandblasted with 250 μm Al_2O_3 particles at 0.60 MPa or lased with different parameters as follows: 2 W-20 Hz, 2 W-30 Hz, 3 W-20 Hz, 3 W-30 Hz.

The bonding surfaces of the test specimens received surface treatments as follows:

Group 1: Control (without any pre-treatment)
Group 2: Alumina abraded with 250 µm Al_2O_3 particles at 0.60 MPa
Group 3: Lased with Er,Cr:YSGG laser at 2 W-20 Hz
Group 4: Lased with Er,Cr:YSGG laser at 2 W-30 Hz
Group 5: Lased with Er,Cr:YSGG laser at 3 W-20 Hz
Group 6: Lased with Er,Cr:YSGG laser at 3 W-30 Hz

In group 2, specimens were treated by alumina abrasion with an abrasive blaster system and carbide-lined micro-pencil (Silfradent, S. Sofia-Forli, Italy). The nozzle (1.0 mm diameter) was held in light contact with each specimen and moved across the PMMA specimen for approximately 1 min with 250-µm aluminum oxide particles as the sandblasting medium at a pressure of 0.60 MPa (MN/m^2).

The laser etching procedures (groups 3, 4, 5 and 6) were performed with an Er,Cr:YSGG laser system (Waterlase MD; Biolase Technology, San Clemente, CA) operating at a wavelength of 2,780 nm, a pulse duration of 140–200 µs, and repetition rates of 20 Hz or 30 Hz. The power output was set at 2 W or 3 W according to the test protocols. Air and water sprays from the handpiece were adjusted to a level of 85% air and 85% water for 2 W and 3 W power outputs to prevent the acrylic surface from overheating. Laser energy was delivered through a fiber optic system to a sapphire tip terminal 600 µm in diameter and 6 mm long. The focused laser beam was aligned to the polymerized acrylic surface perpendicularly at 1 mm, and the area to be bonded with soft liner (a half portion of each acrylic resin surface) was treated manually in a sweeping fashion in accordance with the manufacturer's instructions for etching. Visual comparisons of the treated samples were examined by scanning-electron microscope (SEM) at magnification x1000.

After surface treatment, the specimens were secured in gypsum molds (Moldbaster S; Heraeus Kulzer GmbH, Hanau, Germany). During application of the soft lining, half of the base area was masked with a thin clear plastic sheet so that a specimen was produced in which half of the soft lining was bonded and the other half was free. The soft material was then mixed as required and applied using the technique specified and using the appropriate adhesive. Primo adhesive of Molloplast-B (Detax, Ettlingen, Germany) was applied onto the adherent surfaces of the specimens. The material was compressed using a plastic sheet and a plate of glass and cured using the recommended procedure. The processed flasks were left to cool at room temperature for 20 min and were then kept under running tap water for 10 min. Specimens were then stored in distilled water at 37^0C for one week (18).

A universal testing machine (Instron Corp., Canton, MA, USA) was used to peel the soft lining materials at an angle of $180^0$and a constant cross-head speed of 5 mm/min. The force needed to cause failure and the modes of failure were recorded. Peel bond strength (N/mm= MPa) was calculated as follows:

$$PS= \frac{F}{W}\left(\frac{1+\lambda}{2}+1\right),$$

where the F is the maximum force recorded (N), W is the width of the specimens (mm), and λ is the extension ratio of the liner (the ratio of the stretched to the unstretched length). The denture base material/soft lining material interface was analyzed with a stereo microscope (Olympus SZ 40, SZ-PT, City, Japan), and the failure modes were characterized as cohesive, adhesive, or mixed depending on whether the fracture surface was in the soft liner only, at the denture base-soft liner interface only, or in both, respectively.

Statistical analyses were performed with SPSS for Windows 15.0 (SPSS Inc., Chicago, IL, USA). A two-way ANOVA was used for comparing the groups and acrylic materials at a confidence interval of 95%.

RESULTS

Surface evaluations of the samples were performed with SEM (Fig 1-5). Surface morphology was changed after the surface pretreatments. In sandblasting groups, residual of the AL_2O_3 particles were seen in the samples. Er;Cr;YSGG laser treatment at 3 W-20Hz irradiation has more effect on the PMMA, which results more irregularities on their surfaces than the other pretreatments.

The mean and standard deviation (SD) peel bond strength values of the test specimens are shown in Table 2. The peel bond strength values were significantly influenced by the test protocols and tested materials ($p<0.001$). Different test protocols influenced the peel bond strengths of different test materials.

Peel bond strength values ranged from 3.16±0.64 MPa to 4.74±0.74 MPa in the Paladent group. The highest values were observed in group 5 (lased 3 W, 20 Hz), while the lowest values were recorded in group 2 (sandblasted with Al_2O_3). According to the comparisons of groups, in the Paladent group, the values obtained were as follows: group5 > group 3 > group 4 > group 6 > group 1 > group 2. Significantly lower values were observed in group 2 compared to group 5 ($p<0.05$). A significant difference was found between group 5 and group 6.

In the Rodex group, the values obtained were as follows: group 6>4>2>5>3>1 ($p>0.05$). The highest peel bond strength (4.81±1.32 MPa) was observed in group 6 (lased 3 W, 30 Hz), while the lowest peel bond strength (3.89±0.48 MPa) was recorded in group 1 (untreated). No significant differences were found among these subgroups in the Rodex group.

In the Deflex group, the values observed were as follows: group 3>4>5>6>1>2. The highest peel bond strength (5.58±0.66 MPa) was observed in group 3 (lased 2 W, 20 Hz), while lowest peel bond strength (3.10±0.55 MPa) was recorded in group 2 (sandblasted with Al_2O_3). Significantly lower values were obtained in group 2 compared to the other groups ($p<0.05$).

According to the acrylic material comparisons, in group 1, the Deflex specimens exhibited higher values compared to the Rodex and Paladent specimens ($p<0.05$). No significant differences were found between the Rodex and Paladent specimens ($p>0.05$). In group 2, significantly higher values were observed in the Rodex specimens compared to the Paladent and Deflex specimens ($p<0.05$). No significant differences were found between the Paladent and Deflex specimens ($p>0.05$). In group 3, the Deflex specimens exhibited higher values compared to the Paladent ($p<0.05$) and Rodex ($p<0.001$) specimens. No significant differences were found between the Paladent and Rodex specimens ($p>0.05$). In group 4, the Deflex specimens showed higher values compared to the Rodex ($p>0.05$) and Paladent ($p<0.05$) specimens. No significant differences were found between the Rodex and Paladent specimens ($p>0.05$). In group 5, the Deflex specimens exhibited higher values compared to the Paladent ($p>0.05$) and Rodex ($p<0.05$) specimens. No significant differences were found between the Paladent and Rodex specimens ($p>0.05$). In group 6, the Rodex specimens exhibited higher values compared to the Deflex and Paladent specimens ($p>0.05$).

Modes of failure in each group of the specimens are shown in Table 3. Stereo microscopy views revealed primarily dominant microstructures of mixed failure surfaces in all laser pretreatment groups. Conversely, adhesive failure modes were typical in all of the sandblasting groups except the Rodex group. These findings are also compatible with the SEM evaluations.

DISCUSSION

One of the most serious problems with soft denture liners is the failure of adhesion between the soft denture and the denture base [2,9,11,12,15)]. Different techniques have been used to increase the bond strength between the acrylic resin denture and the soft lining material. However, there have not been enough published articles investigating the effect of laser surface treatments on peel bond strength of soft lining material to acrylic denture resin. The present study compared the effect of air abrasion and Er;Cr;YSGG laser treatment with different pulse durations on the peel strength of silicone-based soft denture liner to three different resins. The null hypothesis that the air abrasion and laser treatment with different pulse durations would improve the peel bond strengths of silicone-based soft denture liner to different denture resins was partially rejected in terms of the pretreatment technique.

Several different types of laboratory tests are available to investigate the bond strength of soft linings to denture base materials [4,6,8,11,34,38)]. In previous studies [36,37)], it was concluded that bond strength characteristics can vary according to the test method used. The most commonly used tests to date are the peel, tensile and shear tests [6,34,35)]. Scientifically, the peel test has multiple advantages. The peel test has been reported to be a more meaningful test for predicting the ability of a material to bond in a clinical setting because debonding normally initiates at the exposed edge of the lining through an apparent peeling process [8)]. The peel test is the only method in which failure proceeds at a controlled area, and the peel force is a direct measure of the work of detachment [8,11,34)]. In addition, the nature of the stresses exerted on the edges of the union is considered to be more closely represented by a peel test [8,11,34)]. However, the results obtained from peel tests were unsatisfactory because of a higher probability of cohesive failure in the soft materials, and the results obtained in a peel test are influenced by the compliance as well as the thickness of the materials [35,38,39]. In the present study, we used the peel bond strength test method.

The results of the present study showed that Er, Cr:YSGG laser irradiation increased the bond strength of the acrylic denture base resin to the silicone relining material. Heat-cured acrylic resin with laser pretreatment at 3 W, 20 Hz showed significantly increased bond strengths to the Molloplast-B compared to the other pretreatment groups. Different pulse durations and energy levels caused different peel bond strength values. However, sandblasting the denture base resin with Al_2O_3 significantly decreased the bond strength of the acrylic denture base resin to the silicone relining material. The different results of this study may be caused by the different chemical structures of the resins and their surface characteristics after the pretreatment procedures.

Jacobsen et al. [11] studied the effect of lasing and sandblasting in a similar fashion to the current study, but they found that altering the PMMA surface by sandblasting with 250 μm Al_2O_3 particles or lasing with a CO_2 laser reduced the peel strength values when compared to untreated surface test specimens. In their study, Usumez et al. [4] compared the bond strength and adhesion of denture liner (Molloplast-B) to alumina-abraded or laser heat-cured polymethyl methacrylate denture base resin. They found that lasing and alumina abrasion of the PMMA before resilient-material application resulted in higher mean tensile bond strengths than those of control specimens, but these increases were not statistically significant. Jacobsen et al. [11] reported that surface treatment with a CO_2 laser was ineffective in reducing adhesive failure of soft-lined prostheses in a clinical situation. In their study, Akın et al. [24] investigated the effect of different surface treatments of PMMA acrylic denture base resin on the tensile bond strength of a silicone-based soft denture liner. They found that altering the polymethyl methacrylate surface by Er: YAG laser significantly increased the bond strengths of PMMA/silicone specimens; however, sandblasting before applying a lining material had a weakening effect on the bond [24]. In their study, they found that surface treatments with Nd: YAG and KTP lasers were found to be ineffective in increasing the strength of the bond and generated different bond values but these differences were not statistically significant [24]. They explained the difference between the Er: YAG laser bond strength and that generated by the Nd: YAG and KTP lasers by the high energy of the Er: YAG laser [24]. These controversial results may be explained by the type of lasers, differences in the applied energy and different structures of denture base resins. One possible explanation for the different effects between lasers might be the different absorption capacity of resin materials.

The different behaviors of the denture base acrylic resins may be related to their chemical properties [40] depending on the type of solvent used [14]. It has also been reported that the bonding between resilient lining materials and denture base materials is affected by the nature of the denture base material [40]. Three base polymers with different chemical compositions were used in the present study. The Deflex group had greater bond strengths with Molloplast-B than the Paladent and Rodex groups. The relatively high scores of the Deflex group can also be explained by the material's compatibility with (or affinity for) Molloplast-B.

Laser application is also believed to lead to chemical changes on acrylic films, which may bring about shortening of the chain length and cross-linking of the chains [41]. These events were believed to be responsible for the observed increases in the bond strength values. The surface energy between the denture base material and the resilient denture lining material should be clear because the force required to produce peeling depends on the adhesive surface energy [7]. The surface energy is affected by the surface treatment, and the energy depends on the surface geometries [8, 11]. The peel energies required on flat surfaces and curved surfaces are quite different [7]. Roughening of the surfaces of the acrylic denture resin is also believed to affect the bond strength with soft lining material in a positive way [32]. Storer et al. [25] reported that sand-blasting the acrylic resin surface before placing a resilient liner improved the strength of the bond, with the slightly irregular surface providing mechanical locking for the soft material. In contrast, Amin et al. [26] found that roughening the acrylic resin base by alumina abrasion before applying a lining material had a weakening effect on the bond. Similar to Amin and Jacobsen's studies, in the present study, it was found that sandblasting the denture base resin with Al_2O_3 significantly decreased the bond strength of the polyamide resin to the silicone relining material. In the heat-cured and cross-linked resin groups, there were no significant differences after sandblasting. In the literature, authors have different comments about the decrease in the bond strengths with acrylic resin and soft liners. According to Usumez et al. [4], the size of the irregularities created by the alumina-abrasion medium may not be sufficient to allow the resilient lining material to flow on it. Amin et al. [26] proposed that lower bond strengths were due to stresses that occurred at the interface of the acrylic resin/soft liner junction. Bolayır et al. [1] argued that the roughening of the surface might have prevented the formation of high bond strength because of the stress concentration resulting from the discontinuities on the surface. Jacobsen et al. [11] also agreed with the idea that the ability of the soft lining material to penetrate into the irregularities of the acrylic resin is important for adhesion. Increasing the viscosity of the resilient materials for a given contact angle and surface tension reduces the penetration of a material into the irregularities on the acrylic resin surface because the penetration coefficient is inversely dependent on viscosity [11]. This could explain the lower bond strengths of sandblasted specimens observed in our study. In our opinion, a possible explanation for the controversial results might also be the remnants of the Al_2O_3 particles. SEM evaluation of the samples showed that roughening methods may improve bonding strengths because of mechanical interlocking, but if the surface of the resin material has debris from the resin material or Al_2O_3 after the pretreatment, it may decrease the bonding of the two materials chemically. The affinity of Al_2O_3 for the resin materials and soft liners might be different from that of the tested materials.

In this present study, irradiation with the Er,Cr:YSGG laser with different pulse durations and energy levels resulted in different bond strengths, results similar to those reported by Tugut et al. [18] although they used an Er: YAG laser. Moreover, they reported that altering the surface of the acrylic resin by laser significantly increased the bond strength to the silicone lining material, results similar to our study. In their study, Tugut et al. [18] found that laser surface irradiation at different energy levels effectively increased the strength of the bond to the soft liner. In this study, we found that different repetition rates and different power outputs resulted in different bond strengths to the soft liner. Different energy levels have been used by researchers [18] with different lasers, but different repetition rates have not been investigated for the Er,Cr:YSGG laser in the surface treatments of acrylic resins.

Although it has been argued that the results of in vitro studies cannot be extrapolated to in vivo conditions, it has been claimed that they may help predict the outcome of clinical applications.

Kulak-Ozkan et al. [42] investigated the effect of thermocycling on the tensile bond strength of six silicone-based resilient denture liners and reported that the tensile bond strength of Parmaflex decreased after thermocycling. However, this decrease was not found to be statistically significant. Elias et al. [40] investigated the effect of thermocycling on the tensile and shear bond strengths of soft liner materials to a denture base acrylic resin. They found that all soft lining materials tested in their study showed a significant decrease in bond strength on acrylic denture base resin after thermocycling, but all the soft liners they tested had higher bond strengths to the denture base than those reported as acceptable for clinical use. Aging of the denture is also an important parameter for the survival of these restorations [40, 42, 43]; the effect of the aging method usually decreases the bond strength, but the amount of this decrease is much more material dependent. Adding the aging factor might add complexity to the understanding of the primary adhesive relationship between the materials.

In further studies, the effect of thermocycling on the bond strength of resin base materials and soft liners after laser and sandblasting pretreatment may also be studied and compared to the current knowledge base on base-liner bonding.

Conclusions

Silicon-based soft lining material tested showed similar peel-strength with and without laser treatment. Heat cured acrylic resin, PMMA, may benefit from Er;Cr;YSGG laser treatment at 3 W-20Hz irradiation. Air-abrasion of polyamid resins should be avoided not to impair their peel bond strengths to silicon-based soft denture liners.

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Figure Legends

Figs 1a-c. SEM images of the control group a) Deflex, b) Paladent, c) Rodex.

Figs 2a-c. SEM images of the air abraded groups a) Deflex, b) Paladent c) Rodex.

Figs 3a-d. SEM images of the laser treated groups Deflex at a) 2w 20 Hz, b) 2w 30Hz, c) 3w 20 Hz, d) 3w 30 Hz. Note the surface irregularities after laser applications in all groups.

Figs 4a-d. SEM images of the laser treated groups Paladent at a) 2w 20 Hz, b) 2w 30Hz, c) 3w 20 Hz, d) 3w 30 Hz. Note the surface irregularities in all groups.

Figs 5a-d. SEM images of the laser treated groups Rodex at a) 2w 20 Hz, b) 2w 30Hz, c) 3w 20 Hz, d) 3w 30 Hz. Note the surface irregularities in all groups.

Figure 1

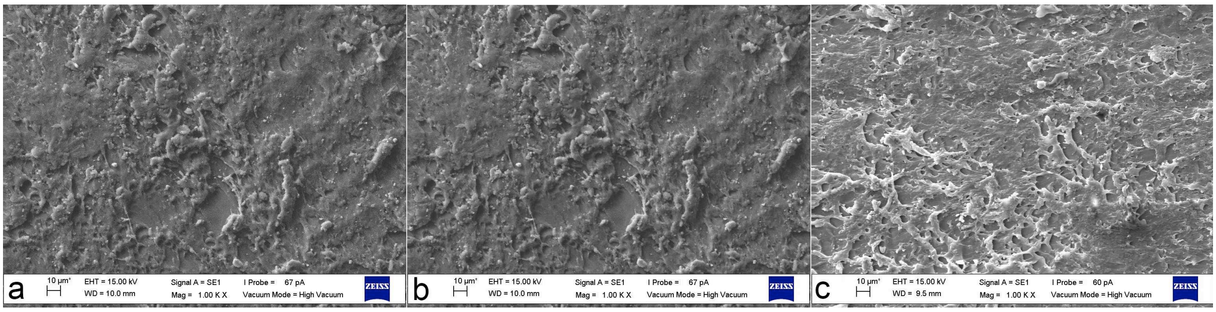


Figure 2

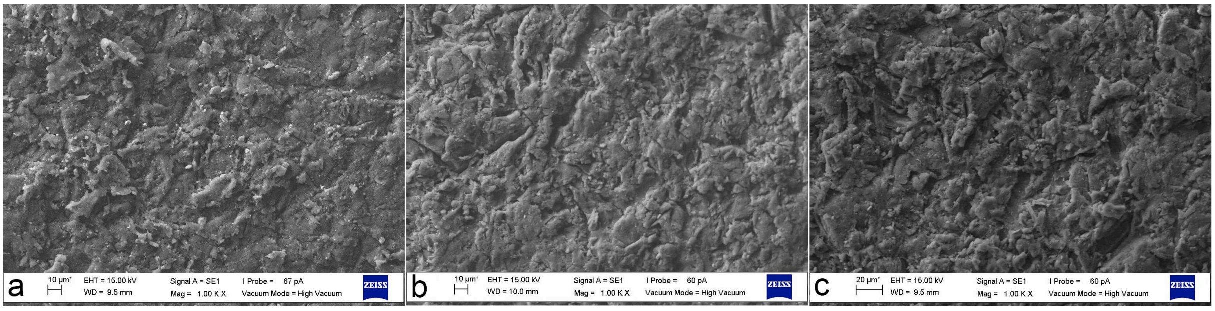
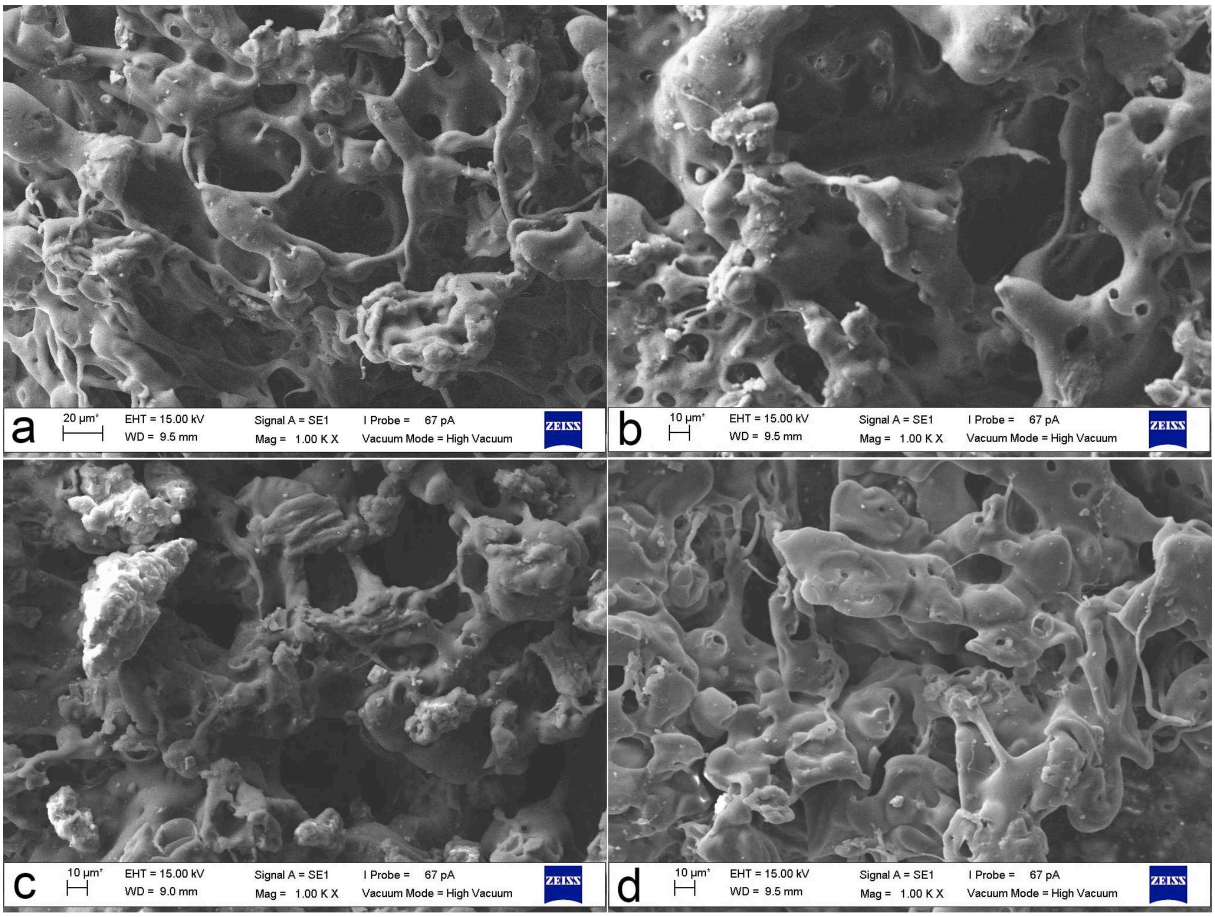


Figure 3



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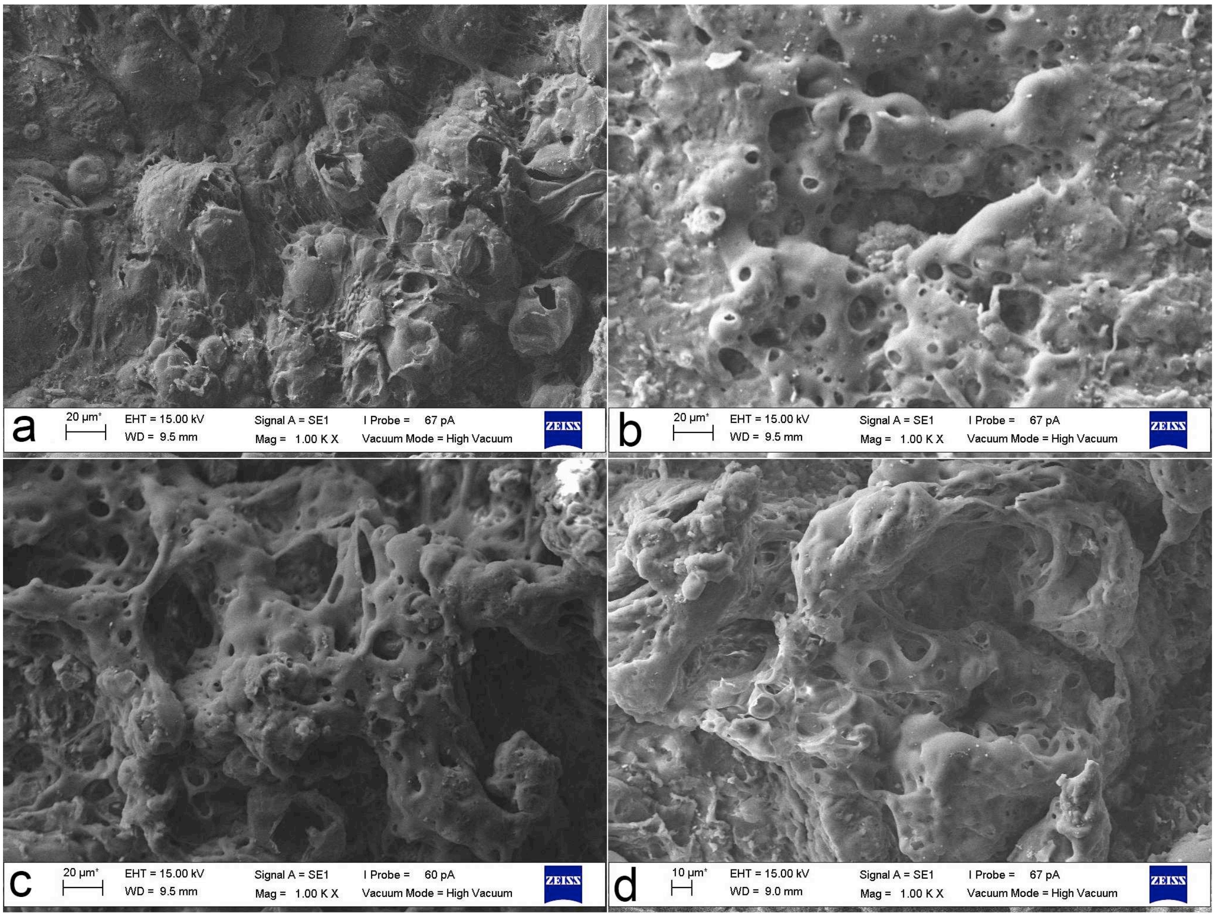
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EHT = 15.00 kV
WD = 9.5 mm
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Mag = 1.00 K X
I Probe = 67 pA
Vacuum Mode = High Vacuum
ZEISS
b
20 µm*
EHT = 15.00 kV
WD = 9.5 mm
Signal A = SE1
Mag = 1.00 K X
I Probe = 67 pA
Vacuum Mode = High Vacuum
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c
20 µm*
EHT = 15.00 kV
WD = 9.5 mm
Signal A = SE1
Mag = 1.00 K X
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d
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I Probe = 67 pA
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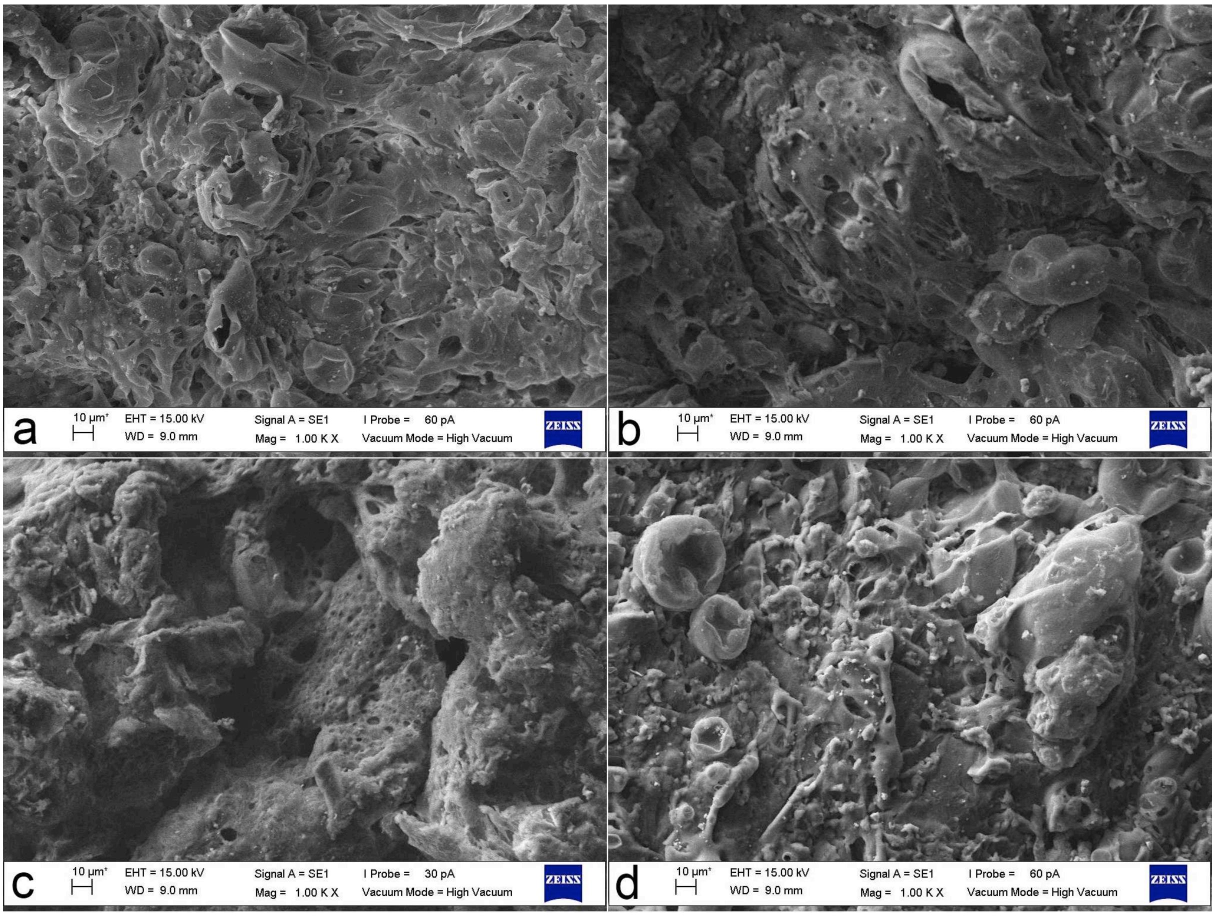
ZEISS

Figure 5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b
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EHT = 15.00 kV
WD = 9.0 mm
Signal A = SE1
Mag = 1.00 K X
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c
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EHT = 15.00 kV
WD = 9.0 mm
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d
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EHT = 15.00 kV
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Table 1.Materials used in this study

Material	Type	Manufacturer
Rodex	Heat-polymerized improved with cross-linked denture base acrylic resin	Rodont, Srl Milan, Italy
Paladent	Heat-polymerized denture base acrylic resin	Heraeus Kulzer GmbH, Wehrheim, Germany
Deflex	Polyamide based-injection molded denture material	Nuxen SRL, Ayacucho 1053 3-A, Cap. Fed. Buenos Aires, Argentina
Molloplast-B	Heat-polymerized silicone-based resilient liner	Detax, Karl Huber GmbH and Co., KG Ettlingen, Germany
Primo adhesive	Adhesive	Detax, Karl Huber GmbH and Co., KG Ettlingen, Germany

Table 2. The results of peel bond strength values (in MPa)

Peel bond strength (MPa)						
	Groups (Mean±SD)					
Materials	Group1	Group 2	Group3	Group 4	Group5	Group 6
Paladent	$3.64\pm0.49^{A,B,a}$	$3.16\pm0.64^{A,a}$	$4.29\pm0.36^{A,B,a}$	$3.97\pm0.64^{A,B,a}$	$4.74\pm0.74^{B,a}$	$3.92\pm0.87^{A,a}$
Rodex	$3.89\pm0.48^{A,a}$	$4.46\pm0.26^{A,b}$	$3.90\pm0.41^{A,a}$	$4.60\pm0.96^{A,a,b}$	$3.96\pm0.87^{A,a,b}$	$4.81\pm1.32^{A,a}$
Deflex	$4.58\pm0.54^{A,b}$	$3.10\pm0.55^{B,a}$	$5.58\pm0.66^{A,b}$	$5.41\pm0.75^{A,b}$	$5.39\pm0.53^{A,a}$	$4.64\pm0.54^{A,a}$

*Superscript capital letters indicate significant differences ($p<0.05$) whereas same capital letters indicate no significant differences among the groups in each acrylic material ($p>0.05$). Superscript lower case letters indicate significant differences ($p<0.05$) whereas same lower case letters indicate no significant differences among the acrylic materials in each groups ($p>0.05$).

Table 3. Modes of failure in each group of specimens

Failure mode			
	Materials		
	Deflex	Paladent	Rodex
Group 1	8 mixed (80%), 2 adhesive (20%)	10 mixed (100%)	10 mixed (100%)
Group 2	10 adhesive (100%)	10 adhesive (100%)	4 adhesive (40%), 6 mixed (60%)
Group 3	10 mixed (100%)	10 mixed (100%)	10 mixed (100%)
Group 4	10 mixed (100%)	10 mixed (100%)	10 mixed (100%)
Group 5	10 mixed (100%)	10 mixed (100%)	10 mixed (100%)
Group 6	10 mixed (100%)	10 mixed (100%)	10 mixed (100%)